CPUC Energy Storage Use Case Analysis

Transmission Connected Energy Storage

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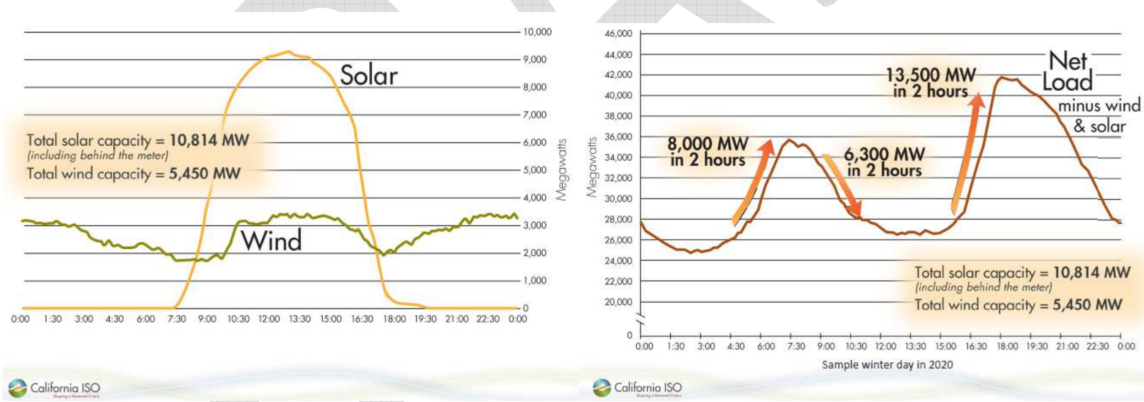
1. Overview

1.1 Introduction

Wind and solar resources have characteristics of variability and sometimes high production forecast errors. Many of these technologies lack the capability to exert control over the time of production and dispatch of the energy. There are a variety of tools at the disposal of system operators to accommodate this increased variability and forecast uncertainty, one of which is energy storage. This use case describes the use of transmission connected energy storage systems, the associated cost and benefit considerations, policies that impact procurement and operation, and real world examples of projects.

As California moves towards achieving the RPS goal of 33% renewable resource penetration, massive wind farms, as well as large photovoltaic (PV), and concentrated solar power (CSP) systems are being installed on the transmission system. This introduction of intermittent resources will challenge the existing system and resources to provide adequate amounts of flexible capacity to manage ramping events and variability. Some potential negative impacts of high penetration of intermittent resources is conventional resources could be forced to operate at inefficient levels or multiple on/off cycles within a day. The following figures from the California Independent System Operator (CAISO) illustrate grid transitions between power sources and portend the need for enhanced ramp management and frequency regulation capability on the grid.



A large deployment of dispatchable resources will be necessary to manage the penetration of intermittent resources that is expected in California. Failure to have flexible capacity available could result in reliability and curtailment of intermittent resources, which could negatively impact the ability to meet the 33% RPS goals.

Generation facilities are typically financially leveraged projects which carry significant amounts of debt, which needs to be serviced with regular payments to debt holders. Existing California renewables facilities were built under the assumption that renewable energy was a must take resource and whatever they could make could be sold.

Of the different types of storage technologies being considered in this proceeding, utility-scale or bulk storage technologies connected to the high voltage transmission system in the range of 20 MW to > 1,000 MW installed capacity, are suited to address the major operational requirements of the electric system. Historically, the large pumped storage projects in the State were pursued to meet specific bulk system needs and took 10-15 years to plan and complete. Although grid conditions have changed dramatically over the last 30 years, the operating pumped storage projects in California highlight the value of energy storage at the transmission level. The need for additional bulk storage over the next decade and beyond is contingent on determination of new operational requirements by the CAISO for the integration of variable energy resources.

2. Use Case Descriptions

2.1 Objectives

The objective of this document is to describe selected use cases for energy storage deployed and connected to the transmission system. The descriptions and justification of this document assumes deploying energy storage as one alternative amongst a group of alternatives that are typically deployed to meet grid needs. The document assumes monetization frameworks that are existing and currently being planned. This document is not intended to analyze, estimate, or and forecast the changes to the grid in the future. The document does provide an analysis of the benefits and barriers, as well as some policy options that could help the development of future energy storage projects.

2.2 Actors

Name	*Role description*
Storage Equipment Provider	The provider of component(s) necessary to build an operational facility. This could be a single party or multiple parties acting together.
Storage Project Developer	The developer manages or performs permitting, financing, and construction of a site to create a complete project.
Storage Owner/ Operator	Owns, operates, and maintains resource.
Load Serving Entity (LSE)	A load serving entity that procures capacity and energy to serve its retail customers. The LSE pays the CAISO for ancillary services based on a percentage of its load. The LSE may meet its capacity and energy requirements through long-term contracts.
Grid Operator	The grid operator is the California Independent System Operator (CAISO), under the auspices of FERC. In addition to operating the grid, the CAISO operates the energy and ancillary services markets and dispatches generators.
Scheduling Coordinator	The entity that schedules or bids an asset into the CAISO markets. This could be the owner, utility with a contract, or a third party.
Transmission Owner	Owns and manages transmission system lines and substation equipment under FERC jurisdiction, typically at voltages greater than 34 KV.
On-Site Resource	Owner/operator of wind, solar, or conventional resource that install solar. Will often be the same as the storage owner or will be a joint partnership with the

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Owner	storage provider.
FERC	Federal Energy Regulatory Commission with interstate regulatory jurisdiction at the transmission level

2.3 Proceedings and Rules that Govern Procurement Policies and Markets for This Use

Primary Governing Policies:

Agency	*Description*	*Applies to*
CPUC	Energy Storage OIR (AB2514)	Utility
CPUC	Long-Term Procurement Plan (LTPP)	Utility / Owner
CPUC	Resource Adequacy (RA)[1]	Utility / Owner
CPUC	Renewable Portfolio Standard (RPS)	Utility / Owner
FERC	RM11-24-000: Financial Reporting for New Electric Storage Technologies	Utility/Owner
CAISO	Order No. 755 Implementation	Owner
CAISO	Ancillary Service Market Administrator	Owner / Utility
CAISO	Regulation Energy Management (REM)	Owner

Related Governing Policies:

Agency	*Description*	*Applies to*
CA	AB32 California Global Warming Solutions Act	
FERC	Order No. 693	NERC
FERC	Order No. 890[2]	Utility / ISO / Owner
FERC	Order No. 755[3]	ISO / Owner

[1] The CAISO has identified through operational studies the need for increased quantities of flexible capacity to manage the electric grid under the 33% RPS. In the active CPUC Resource Adequacy Proceeding (RA) (11-10-023) a new flexible capacity requirement, beginning with the 2014 RA year, is being evaluated. This important reform to the existing RA program is vital to ensure not only that existing flexible resources continue to be available but that there is incentive for new resources, such as storage, to be built to the extent they have the desired characteristics. The existing RA program that requires procurement of only generic capacity may not ensure that specialized needs of the grid are met under the 33% RPS.

[2] FERC, in Order No. 890 (Preventing Undue Discrimination and Preference in Transmission Service) issued February 16, 2007, modified Schedules 2, 3, 4, 5, 6, and 9 of the pro forma open access transmission tariff (OATT) to make clear that Ancillary Services – reactive supply and voltage control, regulation and frequency response, energy imbalance, spinning reserves, supplemental reserves and generator imbalance services, respectively – may be provided by non-generation resources, such as energy storage resources and demand resources, where appropriate.

CAISO	Renewable Integration Studies	Utility / Owner
CAISO	Ancillary Service Market Administrator	Owner / Utility
CAISO	Flexible Ramping Product	Utility/Third Party
CAISO	Generator interconnection process	Owner/developer
FERC	Order No. 1000	
CEC/CPUC	Loading Order (IEPR)	Utility

It has also been acknowledged by the CAISO and parties in the RA proceeding that a multi-year procurement mechanism for resource adequacy is needed. The CPUC intends to address this issue in the Long-Term Procurement Planning (LTPP) Proceeding. The lack of a multi-year procurement mechanism is a significant barrier to securing financing for capital intensive projects.

The CAISO is also in the process of developing a spot market product for flexible ramp. This is an important development to allow storage resources to provide this product to the extent they are able to do so. This initiative must also be tied to the longer-term requirements for flexible capacity as part of the RA program that is described above. A spot market product will provide short-term, least-variable cost optimization and procurement of needed energy services, but will not provide assured long-term revenue streams necessary to promote investment.

2.4 Location

This use case describes energy storage resources are connected at the transmission system and capable of participating in the CAISO wholesale markets from that location. All of the technologies must meet the permitting and environmental requirements for their region. Some transmission connected storage systems need to be dedicated to a specific generator source (e.g. chiller storage, solar-thermal), many do not. The dispatch of non-generator located bulk storage systems can be directed by a utility or RTO/ISO to meet system needs depending on their capabilities, ranging from unit outages, regulation requirements, emergency power needs, and a variety of ancillary services. The dispatch of generator located bulk storage systems will most commonly be regulated by signals sent to the generator host.

The location of some technologies such as pumped storage, hydroelectric, and compressed air energy storage are determined by a number of factors including geologic and topographic conditions, availability of water (for pumped storage reservoirs), or surface and subsurface conditions for excavation, tunnels. Some of the limitations combined with transmission connection of remote regions could contribute to project costs and risks.

[3] In Order No. 755 (Frequency Regulation Compensation in Organized Wholesale Power Markets) issued October 20, 2011, FERC required that ISOs compensate frequency regulation resources based on the actual amount of frequency regulation service provided in responding to the dispatch signal and discussed the potential superior speed and accuracy of energy storage resources.

There are other technologies, generally smaller in scale, are not dependent upon specific geologic and topographic conditions and may have more flexibility to be located based on electric grid needs, including being suitable for deployment close to the load centers. All technologies have different combinations of capital, development, and on-going costs. A "cost-effectiveness" methodology can be used to estimate the overall value, costs net of revenues, of a project.

2.5 Operational Requirements

Historically, the operational requirements originate from two sources. First, the CAISO defines the operational requirements that a resource must fulfill to connect to its wholesale system to participate in CAISO markets. Those requirements are found the CAISO Tariffs. Second, the CPUC currently defines the resource adequacy requirements that must be met by resource to qualify for and provide capacity to contribute to an LSE's RA requirements. In addition, the determination of system need and authorization for procurement is a result of the CPUC's LTPP proceeding. The LTPP proceeding will define the types, characteristics, and amounts of capacity that are needed to maintain system reliability.

Traditionally, utility RFOs have found the following attributes to be beneficial for flexible resources:

- Capable of being cycled on and off at least 300 times a year
- Capable of multiple starts and stops per day
- Short startup time to full operation, for example 30 minutes or less
- A low minimum output level relative to the maximum output
- Ability to change quickly from minimum to maximum and back
- Ability to provide regulating reserves by responding to the CAISO's Automatic Generation Control ("AGC") signal

2.6 Categories of Transmission Connected Energy Storage

To aid understanding, the bulk storage use case has been segmented into several categories that are mostly based on the location of the storage and the end use it provides. A specific storage project could choose to operate in more than one category, although that is largely dependent on the technology and operational decisions of the storage owner and operator.

Bulk Storage System: Energy storage that is controlled independently of other generation sources. It accomplishes charging and discharging functions through market participation in energy and ancillary services. These systems typically have multiple hours of energy storage capability and also can provide resource adequacy to the system (subject to meeting duration requirements).

Ancillary Services Storage: Energy storage that operates independently of other generation sources. Through market participation, it bids or schedules for charging and discharging, while primarily providing ancillary services. The types and amounts of ancillary

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service it is capable of providing are highly dependent on the operating characteristics of the technology and that specific resource.

On-Site Generation Storage: Energy storage that is located on-site of a non-intermittent resource, mostly base load or flexible resource. Energy storage is used to enhance the ability of the on-site generator to participate. If controls systems develop to allow AGC controls for the on-site generation storage systems themselves, independent of the host generator, that participation would be counted in the bulk storage system or ancillary services storage.

On-Site VER Storage: Energy storage that is located on-site of an intermittent resource such as wind and solar. These storage deployments are used to enhance the capacity, energy, or ancillary services revenues of that generator. Some technologies, such as batteries, may choose to operate a part of the battery independently of the on-site generation source. That participation would be counted in either the bulk storage system or ancillary services storage.

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2.7 End Uses

	End Use	BulkSystem	A/S Only	On-Site Generation	On-site VER	Notes
	Frequency Response					Currently provided for free from generators with this capability. Compensation mechanism would need to be defined to incent more generators to offer this. Energy storage could offer this.
ISO/ Market	Frequency regulation	P	P	P	S	
	Spin	P	P	P	S	
	Ramp	P	P	P	S	Ramp is likely to be a 15 minute product.
	Black start	S	S		S	Currently provided for free from generators with this capability
	Real-time energy balancing	P	S	P	P	The definition of this end use is not clear and is most likely already included within the other end uses.
	Energy arbitrage	P		P	P	The resource will take advantage of lower energy prices by charging and higher prices by discharging. Historically, prices have been lower at off-peak times and higher at on-peak times.
	Resource Adequacy	P	S*	P	P	*(If new "flexibility RA" product created. Not eligible for traditional RA)
Generation	Intermittent resource integration: wind (ramp/voltage support)				P	Relevant only if more valuable than market participation
	VER/ PV shifting, Voltage sag, rapid demand support				P	Relevant only if more valuable than market participation
	Supply firming				P	Relevant only if more valuable than market participation
Transmission / Distribution	Peak shaving: load shift					Redundant with 12 and/or 14
	Transmission peak capacity support (deferral)	S		S	S	Location-specific benefit; requires appropriate siting. FERC-jurisdictional benefit
	Transmission operation (short duration, system reliability)					Location-specific benefit; requires appropriate siting. FERC-jurisdictional benefit
	Transmission congestion relief	S		S	S	Location-specific benefit; requires appropriate siting.
	Distribution peak capacity support (deferral)					Not applicable because by definition this document relates to Transmission connected assets, not assets on the distribution grid.
	Distribution operation (volt/VAR support)					Not applicable because by definition this document relates to Transmission connected assets, not assets on the distribution grid.

P (Primary): This is the main operational plan for the energy storage and its business base is based on this benefit.

S (Secondary): This benefit is provided when not seeking the primary benefit.

3. Cost Effectiveness Analysis

3.1 Framework for Analysis

This framework intends to provide focus in comparing different technologies and how benefits of certain technologies impact the market value of resources with the current system. To the extent that the current system cannot account for benefits, they can be listed in the barriers.

	← Time →		
Revenues			
Capacity Revenues for RA contributions			
Energy Market Revenues (includes arbitrage)			
Ancillary Service Market Revenues (regulation, spin, non-spin, ramping, black start)			
Costs			
Fixed Costs (capital costs, labor, financing, ROE, etc.)			
Variable O&M (charging fuel, efficiency losses, emissions, wear & tear, start-up, operations, maintenance, etc.)			
Net Value			

3.2 Direct Benefits

The end uses that can be provided are a function of the characteristics of a technology, the size, and operational decisions. This table is definitive guide of all the primary and secondary uses.

	End Use	*Relevant Portion of Framework*	*How the benefit is currently captured?*
	Frequency Response/ Inertia	Not included	This is currently not a market product and is currently provided by generators for free. If CAISO determines that the need for additional frequency response or inertia, a product would incent the development of resources to provide the service.
ISO Spot Market	Frequency regulation	AS Revenue	This is partially monetized by the ancillary services markets. CAISO is the process of implementing FERC Order 755 that pays for regulation

			services based on performance.
	Spin/Non-Spin	AS Revenue	This is monetized by the ancillary services markets.
	Ramp	Energy Revenue	This is partially monetized by the existing flexible ramping constraint in the ancillary services markets. The CAISO is still developing the complete flexible ramping product.
	Black start		
	Real-time energy balancing[4]	Energy Market Revenue	
	Energy arbitrage	Energy Market Revenue	This is monetized by the energy markets.
Forward Products	Resource Adequacy	Capacity Revenue	This is partially monetized by capacity payments. The RA adequacy proceeding at the CAISO is considering having differentiated products for RA, which would change the existing revenue streams.
Generation	Intermittent resource integration: wind (ramp/voltage support)	Capacity/Energy/ AS Revenue and/or Variable cost	Could be captured to the extent that the storage improves generator's sources of revenues or if ISO adopts an integration charge, it can be included.
	VER/ PV shifting, Voltage sag, rapid demand support	Capacity/Energy/ AS Revenue	Could be captured to the extent that the storage improves generator's sources of revenues or if ISO adopts an integration charge, it can be included.
	Supply firming	Capacity/Energy/ AS Revenue	Could be captured to the extent that the storage improves generator's sources of revenues or if ISO adopts an integration charge, it can be included.
Transmission / Distribution	Peak shaving: load shift		For The function of load shifting is monetized by the "energy arbitrage" function and for transmission asset deferral refer to "transmission peak capacity support."
	Transmission peak capacity support (deferral)		Can be monetized if the asset is deemed to be part of the transmission rate base. See section 4 for relevant barriers.
	Transmission operation (power factor support, short duration performance system, reliability)		Can be monetized if the asset is deemed to be part of the transmission rate base. See section 4 for relevant barriers.
	Transmission congestion relief	Energy Market Revenue	Transmission congestion is compensated through congestion

[4] The CAISO originally defined load following to be variability and uncertainty between the regulation market and HASP markets. With the introduction of the flexible ramping constraint and flexible ramping product, the CAISO has turned part of load following into an ancillary services and the other part to be integrated into the real-time energy markets.

			revenue rights and higher LMP prices.
	Distribution peak capacity support (deferral)	Not Applicable	This document relates to transmission connected assets, not assets on the distribution grid.
	Distribution operation (volt/VAR support)	Not Applicable	This document relates to transmission connected assets, not assets on the distribution grid.

3.3 Other Beneficial Attributes

Benefit Stream	***Relevant Portion of Framework***	***How the benefit is currently captured?***
Flexibility (Dynamic Operations)	Variable Costs Energy Market Revenues AS Market Revenues	Flexible capacity is provided by energy storage resources to the CAISO energy and ancillary services markets. This benefit is captured by bidding into the CAISO markets and being selected to provide regulation, operating reserves, and flexible ramping. To the extent that a resource is capable of multiple start/stops and have short startup times, these benefits will be taken into account by having lower variable costs, which in turn will result in lower bid costs and increase net value. A lower bid cost will increase utilization of resource.
Reduced Emissions	Variable Costs Energy Market Revenues AS Market Revenues	Starting 2013, California's energy price will reflect the cost of GHG emissions as part of the cap-and-trade rules. A storage facility itself does not have emissions, it benefits when selling energy and ancillary services to the wholesale market. A resource can charge on the hours when generation resources have no emissions or low emissions and compete to discharge at hours when generation resources have higher emissions.
Reduced Fossil Fuel Use	(same as above)	Storage could allow fossil units to operate at a more efficient level. Reduction in fossil use is most directly linked with reduction in GHG emissions.
Increased Transmission Utilization		This benefit is very similar to transmission investment deferral. Bulk storage devices connected to the transmission system could increase utilization of transmission assets or defer upgrades. Current FERC accounting rules prevent a resource classified as a transmission asset from earning wholesale market revenues simultaneously.

Benefit Stream	Relevant Portion of Framework	How the benefit is currently captured?
		Additional clarity from FERC is necessary. Refer to “transmission peak capacity support” in section 3.2. This benefit is very locational dependent and providing such a benefit will constrain operations for charging, discharging, and providing market functions. A transmission benefit could be included provided that energy, A/S, and capacity revenue streams are adjusted to reflect the additional operational constraints due to providing a transmission function.
Power Factor Correction		Same as conventional generators (this service essentially provided for free by conventional generators). Generators can inject reactive power to help with correction of power factor.
Over generation management Increased use of renewables to meet RPS goals	Revenues – Energy Market	At times of over generation, energy storage can help to avoid uneconomic curtailment of RPS and conventional resources. During periods of excess energy, the CAISO energy market prices will become negative and a storage resource that can absorb excess energy can receive compensation for charging. The CAISO currently has a bid floor (the maximum energy unit price for absorbing energy) of - $30 and will lower the bid floor to - $150/MWh in Fall 2013. See section 4 for additional notes.
Full use of assets already invested in by ratepayers	Revenues – Energy, Ancillary Services, or Capacity Fixed and Variable Costs	Storage could be used to enhance an existing generation resource by allowing it to offer more capacity, energy, or ancillary services and increasing its revenues. On-site to conventional generator only.
Faster build time	Fixed Costs	If certain technologies are faster to build then that benefit would be reflected in the offer price. On the cost side, delayed capital deployment for a certain quantity of capacity will result in lower development cost due to time value of money, leading to a reduced offer price, thus increasing likelihood of selection
Modularity/Incremental build	Fixed Costs	Same analysis as "faster build time." Key Benefit here is delayed deployment of capital resulting in lower offer price

Benefit Stream	*Relevant Portion of Framework*	*How the benefit is currently captured?*
Reduced System Costs	AS Market Revenues	Some technologies can respond faster and provide a higher amount of benefit to the system for frequency regulation. This could also reduce the amount of frequency regulation that is ultimately procured by the CAISO. Implementation of Order 755 will implement pay for performance regulation. In this case, resources that can respond faster to regulation signals may receive a higher compensation – whether this occurs and its value is highly dependent on the amount of storage deployed, bidder behavior, resultant market prices, and the reduced lifetime of storage that may rise from faster dispatch.
Optionality		Resources that are quickly deployable can provide viable alternatives to long lead time assets. Such resources could have an value for optionality, where there is reduced risk by deploying a resource closer to the time that it is need. The optionality value comes from flexibility of deployment date and size. The value arises from multiple effects: • Some storage technologies can be deployed when needed, as opposed to far in advance of need. • The storage is only deployed if needed and the deployment can be timed and sized to match economic and demographic shifts, eliminating the risk of short term overbuilding. A more detailed discussion of the “Optionality” concept is provided in the Appendix section.
Locational flexibility	Fixed Costs Capacity Revenues	This benefit could be monetized in two forms, depending on the nature of the locational advantage. Either (a) Reduced offer price, by being able to site at a more economical location, or (b) located in a capacity constrained region to contribute local reliability requirements, which would lead to increased local RA revenues.
Mobility		Many types of storage can be relocated, including containerized storage and other types (e.g. NGK’s NAS.)
Multi-site aggregation		This is highly situation dependent. It could show in the revenues and costs when comparing different alternatives of single site vs multi-site installations.

3.4 Capital Costs & Relevant Cost Variables

Cost Type	Description
Capital Costs	
Fixed O&M	
Variable O&M	
Duration	
Efficiency	
Housekeeping Power	
Life (year, cycles)	
Degradation	
Cost of replacements	
Development time	

4. Barriers Analysis & Policy Options

Barriers Identified	Relevant Y/N	Explanation
System Need	Yes	*What is the barrier?* There is little clarity around the future needs and attributes for the California system to maintain reliability with 33% renewables. As a result, it is not known what attributes are will needed to manage the future system. *How is it a barrier?* LSEs cannot send definitive signals on their future procurement needs. *What are the potential resolutions?* The LTPP will determine the future system needs and attributes for meeting that need. The LTPP would also provide the authorization for the CPUC jurisdictional utilities to engage in procurement. The storage OIR can ensure that CAISO modeling and CPUC LTPP do not bias against storage being considered in the future needs. LSEs design RFOs and RFPs to be inclusive of all technologies, including energy storage. This allows newer technologies to have a fair consideration and provides the opportunity to compete with conventional technologies.

Barriers Identified	*Relevant Y/N*	Explanation
Cohesive Regulatory Framework	Yes	*What is the barrier?* Existing regulatory framework does not consider storage to be used as a generation asset and transmission asset. The basis of this prohibition is concern that transmission operators are privy to information that would give them an unfair advantage in participating in the markets. The California Transmission Planning Process does not look at demand side resource and does not coordinate system planning with CPUC resource planning processes. *How is it a barrier?* Storage can be used to perform generation and transmission functions. There is a regulatory and decision making gap between the FERC, CPUC, and CAISO's transmission planning processes. Storage which could provide both transmission and generation functions is not able to take advantage of it both benefits in comparisons to other alternatives. *What are the potential resolutions?* CPUC, FERC, and CAISO find an effective way to unlock the ability of storage to provide both transmission and generation function. One solution is to allow the storage to operate as a transmission asset according to a fixed profile. This approach was used for the TransBay Cable. Another option is to allow an independent third-party to bid the storage transmission asset into markets associated with generation functions such as frequency regulation. The California Transmission Planning Process and CPUC resource planning processes can determine ways to coordinate on planning.

Barriers Identified	*Relevant Y/N*	Explanation
Evolving Markets	Yes	*What is the barrier?* The CAISO spot markets are still evolving and new products are still under development. Flexibility products are only spot market products and do not have associated forward products. The current market rules are designed for generation and it results in confusion for demand response and storage. *How is it a barrier?* It is difficult to build a business case on not yet developed products and with volatile spot market prices. *What are the potential resolutions?* The CAISO is in the process of implementing pay for performance regulation, regulation energy management for sub 1-hour resources, updated market models to allow selling ancillary services during charging, and flexible ramping product. The RA proceeding could establish differentiated RA products that include flexibility. See RA section. Design of future spot and forward product should be inclusive of generation, demand, and storage resources.

Barriers Identified	Relevant Y/N	Explanation
Resource Adequacy (RA) Value	Yes	*What is the barrier?* There are no clear rules for the RA credit that energy storage can count for. *How is it a barrier?* Energy storage provides capacity that is flexible. The current RA rules do not differentiate between flexible RA and non-flexible RA. *What are the potential resolutions?* The RA proceeding is will establish RA rules for energy storage and is investigating having differentiated RA products, including flexible RA. It is not clear if this will be a large enough incentive to help make energy storage case to be cost-effective. The CPUC could develop an interim method to assign an RA value and flexibility for energy storage until RA proceeding is complete.
Cost Effectiveness Analysis	Yes	*What is the barrier?* The current methods of cost-effectiveness evaluation do not consider all of the benefits that energy storage provides. Expectations that storage costs will drop rapidly results in waiting for a future technology. *How is it a barrier?* The relative value of energy storage compared to other resources may not be fully captured in evaluation methods. *What are the potential resolutions?* The energy storage OIR proceeding could define a list of benefits that storage provides and explain how they could be captured in a cost-effectiveness methodology. The storage OIR can perform cost-effectiveness analysis using industry tools to make an estimate on the relative cost-effectiveness of energy storage. The tools and methodology will need to be designed around specific use cases, rather than having a generic use case for all energy storage. Business cases for energy storage should be made

Barriers Identified	Relevant Y/N	Explanation
		with the current prices and in uses where energy storage is cost-effective currently. Additional applications for storage could be available, if costs decrease.
Cost Recovery Policies	Yes	*What is the barrier?* Lack of long-term contracts for energy storage make financing projects difficult. Products that storage provides, such as A/S are not procured on a forward basis through long-term contracts. The current price structures do not allow for the long-lead time, cost uncertainty, and project uncertainty. For example, a significant barrier for pumped storage is the long lead time for development and construction. *How is it a barrier?* Products that storage provides are not procured on a long-term basis, which makes financing those projects difficult. *What are the potential resolutions?* Part of a solution is in progress. The LTPP will determine a system needs and authorize LSEs to procure resources. This could result in solicitations for long-term contracts. Storage developers need the ability to secure long-term contracts (greater than 10 years) to help obtain financing for the projects. The LTPP could allow for a longer lead time for signing contracts in advance of the production date. For example a contract would need to be signed no later than 2009-2010 for a pump storage facility to begin operations in 2020. Alternative pricing structures such as allowing developers recovery of costs for feasibility studies could be a potential solution. Another alternative solution could be for the CPUC to allow for a separate procurement channel to for long-lead time projects.

Barriers Identified	Relevant Y/N	Explanation
Cost Transparency & Price Signals	Yes	*What is the barrier?* The current system does not distinguish between intermittent and non-intermittent resources. These resources are compensated in similar ways. The current CAISO prices for energy and A/S are not likely to result in sufficient market incentive for the development of storage. The CAISO will lower the existing -\$30 bid floor to -\$150 in Fall 2013. This may still not provide a sufficient incentive for resources to dispatch down or absorb energy. *How is it a barrier?* Without the distinguishing between intermittent and non-intermittent resources, the costs of integration of the intermittent resources are not transparent and paid by the parties causing intermittentency. *What are the potential resolutions?* On-site VER energy storage is not valued by the system for reducing the overall variability and uncertainty on the system. An integration cost that is transparent and allocated to intermittent generators would increase the value of on-site VER energy storage. The CAISO bid floor could be lowered.

Barriers Identified	Relevant Y/N	Explanation
Commercial Operating Experience	Yes	*What is the barrier?* Many technologies do not have sufficient operating experience to attract financing. Newer technologies cannot offer warranty and performance guarantees as incumbent technologies. *How is it a barrier?* New technologies find it difficult to compete with incumbent technologies that have less technology risk. *What are the potential resolutions?* Develop additional sources of funding to create pilot projects that help new technologies to build a record of operating experience. Pilot and demonstration projects could also help to prove cost-effectiveness of different uses and technologies. If CPUC believes that there is a societal value from the new technologies, then CPUC can allow flexibility in the terms sheet for aspects of warranty to be relaxed for new technologies. Other stakeholders disagreed and believe that storage should receive equal treatment for warranty terms.
Interconnection Processes	Yes	*What is the barrier?* Storage is not able to help interconnection processes by the TPP and utilities. *How is it a barrier?* Storage is a potential solution that can help projects interconnect to the grid. *What are the potential resolutions?* Allow storage and define rules for storage to participate in interconnection processes.

Barriers Identified	*Relevant Y/N*	Explanation
Optionality Value	Yes	See explanation on optionality in the 'Other Beneficial Attributes' section.

5. Storage and Non-Storage Solutions (This section is still under development)

5.1 Applicable Energy Storage Technologies

(This section is still under development)

The bulk energy storage resources addressed in this use case range in unit size from 10 MW to a few hundred megawatts and store energy ranging from 15 minutes to several hours of discharge time . For convenience in describing the use of these resources, they are categorized as short duration discharge (SDD) capable of storing energy for one hour or less and long duration discharge (LDD) capable of storing energy for multiple hours.

- Examples of SDD storage technologies include megawatt-scale flywheels, above ground CAES and some battery technologies that are currently being commercialized to provide market services such as frequency regulation. In general, the siting of frequency regulation assets is relatively flexible, i.e., the benefit of market services derived is not particularly sensitive to their physical location on the grid or geologic considerations.
- Examples of LDD storage technologies include pumped hydro (PH), compressed air energy storage (CAES), generator storage for gas plants, and, generally speaking, some types of battery technologies. Further, the location of technologies such as PH and underground CAES are severely limited because of geologic and environmental considerations.

Storage Type	*Storage capacity*	*Discharge Characteristics*
Short Duration Discharge (SDD) Energy Storage Technologies (< 1 hour),		
Flywheels, Li-Ion Batteries, Lead-Carbon Batteries (others??)	Driven by capability to meet CAISO duty cycle for frequency regulation and deployed in 20 MW units with discharge / charge cycles less than one hour	Driven by capability to meet CAISO AGC signals for frequency regulation duty cycle.
Long Duration Discharge (LDD) Energy Storage Technologies (> 2 hours)		
Central Energy Storage (CES) technologies, e.g., Pumped Hydro (PH), Underground CAES,	Driven by needs and geologic / geographic compatibility with the technology in unit sizes of 100 MW or larger. Energy delivered for a few hours.	Driven by capability to meet CAISO signals for frequency regulation and [future] ramping management duty cycles,

Distributed Energy Storage (DES) technologies, e.g., Sodium-Sulfur (NAS) Sodium Nickel Chloride (NaNiCl) Lithium Ion (Li-Ion) Above Ground CAES Flow Batteries and others	Driven by grid operations enhanced by distributed backup power with units in the range of 10 to 100 MW. Energy delivered for a few hours	as well as multi-hour discharge capability to enhance grid utilization and/or reliability.
Generator Storage (GS) for Gas Turbines	Driven by capability to provide increased capacity, energy, or ancillary services for gas power plants particularly as outside temperatures increase. Systems typically range in size between 15 and 100 MW, capable of discharging for multiple hours; typically no more than 8 to 12 hours at a time.	Currently operated by plant operator without unique AGC controls for the storage system itself. With further developed pricing by CAISO AGC controls for the storage unit will likely be developed. Currently system provides turbine operator the ability to ramp up or down without cycling for the turbine, and storage system can serve as a load sink according to grid need. In the future system could offer CAISO control of storage system itself.

5.2 Applicable Non-Energy Storage Alternatives

(This section is still under development)

There are a variety of alternatives that are available to provide flexible capacity to the electric system and enable the integration of weather sensitive intermittent resources. Some of the alternatives include:

Supply and Reserve Sharing: Sharing of operating reserves, conventional supply, and loads across a balancing areas increases the pool of available demand-side and supply-side resources available.

Flexible Generation: Flexible generation resources such as hydroelectric power, combustion turbine, and combine cycles have historically provided much of the flexible capacity for the grid. The ability to modify equipment and make upgrades can improve the flexible capacity of the existing generation fleet.

Demand-Side: Demand side programs can provide flexible capacity over multiple timescales.
Economic Curtailment: At times of over-generation, negative energy prices provide generator an economic signal to decrease generation.

More details of the non-storage alternatives are outlined in an NREL paper[5].

6. Real World Examples

6.1 Pumped Storage

Technology Description

Pumped storage hydropower is a modified use of conventional hydropower technology to store and manage energy or electricity. Pumped storage projects store electricity by moving water between an upper and lower reservoir. Electric energy is converted to potential energy and stored in the form of water at an upper elevation. Pumping the water uphill for temporary storage "recharges the battery" and, during periods of high electricity demand, the stored water is released back through the turbines and converted back to electricity like a conventional hydro station. In fact, at many existing pumped storage projects, the pump-turbines are already being used to meet increased transmission system demands for reliability and system reserves. Current pumped storage round-trip or cycle energy efficiencies exceed 80%, comparing favorably to other energy storage technologies and thermal technologies. New adjustable-speed technology also allows pumped storage to provide fast ramping, both up and down, and frequency regulation services in both the generation and pump modes. This is important because many of the renewable energy resources being developed (e.g., wind and solar) are generated at times of low demand and off-peak energy demand periods are still being met with fossil fuel resources, often at inefficient performance levels that increase the release of greenhouse gas emissions.

End Uses

End Use	**P/S**	**Notes**
Frequency Response		Although currently provided for free from generators with this capability frequency response capability may be diminished with OTC and nuclear issues. Storage providers that utilize generators with significant rotating mass can help provide grid stability and system inertia. Due to the fast response

[5] Denholm, P., et al. 2010. The Role of Energy Storage with Renewable Electricity Generation. National Renewable Energy Laboratory. Technical Report NREL/TP-682-47187. January 2010.

		capabilities of pumped storage, in can also provide significant incremental power when needed to minimize or avoid a frequency disturbance.
Frequency regulation	P	Advanced pump turbine units utilizing variable speed technology provide fly-wheel type response via power electronics to adjust power flow. Fast responding, flexible resources such as pump storage allow the CAISO to meet their regulation requirements, which are forecasted to increase in some hours with 33% renewable integration with fewer resources and at lower cost to the system.
Spin	P	Pumped storage stations can provide spinning reserve capabilities in both generation and pumping modes resulting in rapid response (<10 seconds) to system needs.
Ramp	P	As demonstrated in the CAISO's renewable integration operational studies, increased frequency and magnitude of ramps across various time frames will result in the need for additional flexible capacity from fast ramping resources to effectively manage the electric grid under the 33% RPS. This need for additional flexible capacity is currently being addressed in the Resource Adequacy proceeding through the development of a flexible capacity requirement. Forward looking longer term requirements are being addressed through LTPP proceeding. Depending on design specifications, advanced pumped storage facilities can provide exceptional ramping services as fast as 10-20MW per second resulting in 250 – 350 MW of ramping per unit in less than a minute. This is compared to a fast ramping gas fired power plant which move at a rate in megawatts per minute rather than seconds.
Black start	S	Currently provided for free from generators with this capability. However, future capability could be decreased by OTC and nuclear issues. Virtually all pumped storage stations are able to provide black start services with possibly the most significant example of this capability is the grid restoration following the August 2003 Northeast region blackout. The hydro and pumped storage projects in the region led the restoration efforts.
Real-time energy balancing	P	The CAISO renewable integration studies also reflect the need for additional intra-hour load following up and down requirements to address variability and forecast uncertainty under the 33% RPS. Similar to frequency regulation and ramping capabilities, pump turbines can be an energy sink or source in a matter of seconds and be the shock absorber to the grid and truly respond to net load needs.
Energy arbitrage	P	The resource will take advantage of lower energy prices by charging and higher prices by discharging. Historically, prices have been lower at off-peak times and higher an on-peak times. Wind energy is expected to peak at night creating increased instances of over-generation that the CAISO will be

		required to manage. Energy storage can be used to shift production from off-peak to peak periods and possibly even reduce curtailment of renewable energy during off-peak periods.
Resource Adequacy	P	*(If new "flexibility RA" product created. Not eligible for traditional RA) Pump storage qualifies to provide capacity to the load serving entities through the CPUC's Resource Adequacy program. Due to the fast ramping capabilities described above, pump storage can also be utilized to provide the new flexible capacity requirements that are under development and targeted for the 2014 RA year.
Intermittent resource integration: wind (ramp/voltage support)		Relevant only if more valuable than market participation. To expand on RAMP above, when large installations of wind are ramping up or down out of correlation with load, large scale pumped storage can respond inversely to mitigate net load ramping rates that can approach over 4000 MW/hour.
VER/ PV shifting, Voltage sag, rapid demand support		
Supply firming		
Peak shaving: load shift		
Transmission peak capacity support (deferral)	S	
Transmission operation (short duration performance, inertia, system reliability)		
Transmission congestion relief	S	
Distribution peak capacity support (deferral)		
Distribution operation (volt/VAR		

support)		

Costs & Other Variables

Cost Type	
Capital Costs ($/MW and $/MWh)	$1,000,000 - $2500,000/MW and $80 – 250/MWh
Fixed O&M ($/MW)	~ $5000 – 7000/MW
Variable O&M ($/MW)	~ $0.30/MWh
Duration	6 – 14 hours
Efficiency	78 – 82%
Housekeeping Power	< 1 MW
Life (year, cycles)	100 years
Degradation	N/A. There is no performance degradation for pumped storage over time or operating cycles
Cost of replacements	N/A.
Development time	4 – 8 years

Example Project

A pumped storage project currently under development, E.ON Waldeck 2+, has been selected as a relevant example due to market similarities between Europe and California. While existing pumped storage projects in California, such as Helms, were considered, such projects were developed, approved and constructed under a different regulatory structure which is not comparable with the current situation. Waldeck 2+ is a proposed 300MW Pump Storage Project (PSP) located on Lake Edersee in Waldeck, Germany. Waldeck 2+, with an expected COD of 2016, will take advantage of the existing infrastructure at the site, originally built for Waldeck 2 (COD 1975) with 480 MW's and Waldeck 1 (COD 2009) with 135 MW's. The project, with an IRR above 10%, benefits from three major revenue components:

1. Wholesale Market Trading – arbitrage between high and low spot markets
2. Reserve Market Trading
3. Portfolio Effect – beneficial effect on the E.ON fleet by optimizing the hydro-thermal portfolio operation with increased efficiency and flexibility

This new project also address three major challenges of the German generation market – the need for energy storage (by 2030, 30% of the electricity will be generated from renewables), reserve (there is an increasing need for ancillary services due to the growth of volatile/unpredictable renewable energy growth) and flexibility (Germany's generation portfolio is currently dominated by thermal power plants that are less flexible than PSP's. The project will provide shorter start-up times, higher load gradients and black start-up capability for short term reserve products, and frequency control for the German Grid).

The Waldeck 2+ project will be privately financed by E.ON and will earn money from existing spot and reserve markets. In addition, the Waldeck 2+ project will be part of an E.ON regional generation portfolio and will increase the overall value of the portfolio due to the flexibility of the project. Finally, while no long term commitments have been entered into, E.ON does expect that at least a portion of the project will provide a long-term revenue contribution.

Location	Waldeck, Germany
Operational Status	Preparing of final tender documents for equipment, Planned Commercial Operation 2016
Ownership	E.ON
Primary Benefit Streams	Wholesale Market Trading – specifically Energy Arbitrage
Secondary Benefits	Reserve Market – contributing to the reserve markets in Germany. Additional benefits are performance optimization of the E.ON fleet.
Available Cost Information	CAPEX: $329M, project takes advantage of civil works already existing on site.

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6.2 Flywheel

Technology Description

Flywheels rapidly inject and withdraw power from the grid in order to quickly and accurately follow fast-changing dispatch control signals. When generated power exceeds load, flywheels can store this excess energy. When load increases, flywheels return the energy to the grid. Flywheels can respond nearly instantaneously to a system operator's control signal, or up to one hundred times faster than many traditional generation resources. The ability to quickly and precisely respond to moment-by-moment system changes makes flywheels ideally suited to provide end uses that require fast responses, for example, frequency regulation.

End Uses

End Use	**Primary/ Secondary**	**Notes**
Frequency regulation	P	Fast, accurate response provides optimal regulation. Flywheels are capable of providing 100% rated power in seconds.
Spin	P	Fast, accurate response
Ramp	P	Fast, accurate response
Black start	P	
Real-time energy balancing	S	
Resource Adequacy	S*	
Intermittent resource integration: wind (ramp/voltage support)	S	
VER/ PV shifting, Voltage sag, rapid demand support	S	

Cost & Other Variables

Cost Type	
Capital Costs ($/MW and $/MWh)	
Fixed O&M ($/MW)	
Variable O&M ($/MW)	
Duration	
Efficiency	
Housekeeping Power	
Life (year, cycles)	
Degradation	
Cost of replacements	
Development time	

Example Projects

Beacon Power, LLC – Stephentown Project

The Stephentown Project is a 20 MW flywheel energy storage system located in Stephentown, NY that is currently operating and providing Ancillary Services in the New York Independent System Operator (NYISO) wholesale market. The Stephentown plant began operating in January 2011 and is qualified to provide Frequency Regulation service in NYISO. It is owned by Spindle Grid Regulation, LLC and operated by Beacon Power, LLC, which are both subsidiaries of Rockland Power Partners, LP. Beacon Power developed the project, manufactured the flywheels, and integrated the related electronics and other systems for the plant to connect to the grid and accurately follow the grid operator's dispatch signals. The Stephentown facility sits on 3.5 acres and is comprised of 200 flywheels each with a storage capacity of 100 kW / 25 kWh.

As a Limited Energy Storage Resource (LESR) in NYISO, by Tariff requirement the Stephentown Project only bids Regulation service and not Energy in the wholesale market, but does inject and withdraw Energy as part of the provision of Regulation service. The fast and accurate Stephentown Project can ramp to its full capacity (20 MW) in one Frequency Regulation dispatch cycle (6 seconds) and provides continuous (24x7) Regulation service. On average, the Stephentown Project is 10% of the Regulation market capacity, yet provides 25% - 35% of NYISO's Area Control Error (ACE) Correction.

Location	***Stephentown, NY***
Operational Status	Online since January 2011
Ownership	Spindle Grid Regulation, LLC (subsidiary of Rockland Power Partners, LP) Operated by Beacon Power, LLC
Primary Benefit Streams	Frequency Regulation
Secondary Benefits	Renewable integration. Increased fleet efficiency, reduced fuel consumption and emissions. Lower system costs.
Available Cost Information	

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6.3 Generation Storage

TAS Energy- Texas Electric Cooperative

TAS Energy Generation Storage™ on an Electric Cooperative in Texas ERCOT market added 90 MW of added capacity and an improved heat rate. The ambient design conditions were 95F dry bulb and 75F wet bulb. The system installed included a 6.1 million gallon thermal energy storage tank and a 2x60 Hz chiller supplying 7,800 tons/27,431 kwth. The TES tank supplies chilled water for both combined cycle Unites 1&2 and allows the plant operator to pull electricity from the grid at night-time hours (and pricing) to chill the water and have it stored for use the following day during the peak demand. In most cases the system is operated to provide full additional capacity in summer temperatures according to increased grid demand, however the system also provides ancillary services and renewable integration according to price signals.

Location	Texas: ERCOT market
Operational Status	Online 2009
Ownership	Electric Cooperative
Primary Benefit Streams	Capacity
Secondary Benefits	Ancillary Services/Renewable Integration
Available Cost Information	Total project cost ~$35 million
Added Capacity	90 MW

Case Study Links Including Project Details and Pictures:

110 Added MWs on a Pennsylvania facility
90 Added MWs on a Texas Electric Coop
51 Added MWs on a Texas Co-gen Facility
37.5 Added MWs on a Texas Electric Coop

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6.4 CSP with Thermal Storage

Similarly to other storage technologies, CSP with thermal energy storage has a variety of technology developers and designs. The pilot project for CSP with molten salt storage was Solar 2, which was operated by the US Department of Energy (DoE) from 1996 to 1999. At present, the commercially operating plants with molten salt storage are located in Spain, and are in range of 1.4 - 150 MW. There are several larger plants under construction or development in the United States, each utilizing different technology designs. Table 1 shows the major U.S. CSP projects under construction, with and without thermal storage, all of which are scheduled for commercial operations in 2013. The remainder of the section then reviews the designs for three alternative CSP technologies with thermal storage.

Project name, location and on-line date	***CSP type***	***MW***	***Developer and Current Owners***	***Off-takers***
Ivanpah California, **(2013)**	Power tower with steam boiler and *de minimis* auxiliary gas, no storage	392 MW (3 power towers)	BrightSource (developer and minority owner), NRG (majority owner) and Google (minority owner)	Southern California Edison, Pacific Gas & Electric
Mojave Solar, **California** **(2013)**	Parabolic trough, no storage	250MW	Abengoa Solar	Pacific Gas & Electric
Genesis, **California** **(2013)**	Parabolic trough, no storage	250 MW	NextEra (owner)	Pacific Gas & Electric
Solana, **Arizona** **(2013)**	Parabolic trough with 6 hours of thermal storage	250MW	Abengoa Solar	Arizona Public Service
Crescent Dunes, Nevada **(2013)**	Power tower with molten salt receiver and 10 hours of thermal storage	110 MW	SolarReserve (developer and owner), Banco Santander and ACS Cobra (owners)	NV Energy

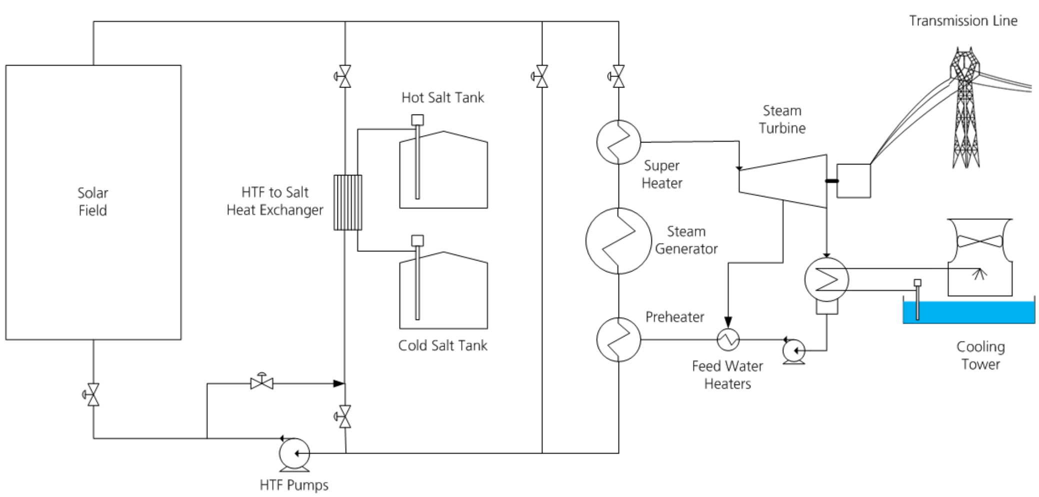
Project Description – Parabolic Trough with Indirect Heating of Molten Salts

This section provides a brief description of a parabolic trough plant with an indirect, two-tank molten salt thermal energy storage (TES) system. The design is based on the 250 MW Abengoa Solar Solana project with 6 hours of thermal energy storage under contract to Arizona Public Service. This technology uses a field of parabolic trough collectors to heat a synthetic oil heat transfer fluid (HTF) up to approximately 735°F. The thermal energy collected in the solar field can either be used to generate steam to power a conventional steam turbine or to charge the thermal energy storage system for later use. The storage system is comprised of a series of cold and hot salt storage tanks and heat exchangers use to transfer energy to the storage system from the solar field or from the storage system back to the HTF to be used to generate steam in the power plant. The salt is a 60:40 mixture of sodium and potassium nitrate salts, and is maintained in a liquid (or molten) state in the storage system. To charge the storage, cold salt at approximately 535°F is taken from the cold salt storage tank and passed through the heat exchanger where it is heated by hot HTF from the solar field to approximately 730°F. The heated salt is then return ed to the hot salt storage tank where it is stored for later use. To discharge the storage, the hot salt is circulated back through the heat exchanger to rewarm the HTF. The hot HTF is then used to generate steam to run the steam turbine. The salt is cooled in the process and returned to the cold salt storage tank.

The Solana plant has two 140MWe steam turbine/generator sets. The internal station load for the power cycle, solar field HTF circulation pumps, thermal energy storage system, and BOS consume about 10% of the electricity generated. The plant will nominally deliver 250 MW net electricity to the utility. The Solana thermal energy storage system is sized to store enough energy to generate 6 hours of electricity at full load. The solar field is sized to deliver enough thermal energy to power a 400 MWe power cycle under design solar conditions. As a result, during a typical summer day, the solar field produces more energy than is needed to operate the power plant at full load. Under these conditions excess thermal energy is sent to charge the storage system. At the end of the day the stored energy is used to continue operating steam turbine well after sunset. The stored energy can be used to maintain power generation during intermittent clouds. The plant has been designed to have a high capacity factor during the Arizona summer peak (week days, noon to 8pm standard time, June to September).

During the winter, the thermal energy collected by the parabolic trough solar field is reduced, such that all energy collected by the solar field can be sent directly to the steam turbine. Alternatively, all energy collected by the solar field can be stored for later use. This allows the power plant to be dispatched to better meet the utility's winter load profile. The Arizona winter load is characterized by a double peak. One peak occurs in the early morning for space and water heating, and one in the evening for heating, lights and TV. The utility load is near its daily minimum during the middle of the day when the solar plant would need to be operating if it did not have storage. The Solana power purchase agreement allows the utility to request the plant dispatch generation during one or both of the utility winter peak periods. The power purchase agreement is designed to compensate the operator for any reduced generation that may occur due to utility dispatch of the plant.

The storage system is considered indirect because the heat transfer fluid used in the solar field is different than the fluid used in the storage system, requiring a heat exchanger. The result of this is that the temperature of the HTF going to the power plant is about 20°F lower when energy is being discharged from storage. This results in a slightly lower power cycle efficiency and gross electric output from the generator. Because station parasitics are lower during TES discharge, the net generation of the plant is nearly the same. The annual net solar to electric efficiency of a parabolic trough plant with storage is higher than the a parabolic trough plant without storage. This is because the power cycle is operated at or near full load most of the time; the plant has fewer starts and shorter periods between operation.



Process flow diagram for conventional oil heat transfer fluid parabolic trough plant with thermal energy storage

Location	***Near Gila Bend, Arizona***
Operational Status	Under construction, commercial operations in 2013
Ownership	Abengoa Solar
Primary Benefit Streams	Energy, semi firm solar capacity, ability to dispatch power generation to better match peak demand
Secondary Benefits	Power quality, potential ancillary services
Available Cost Information	NA

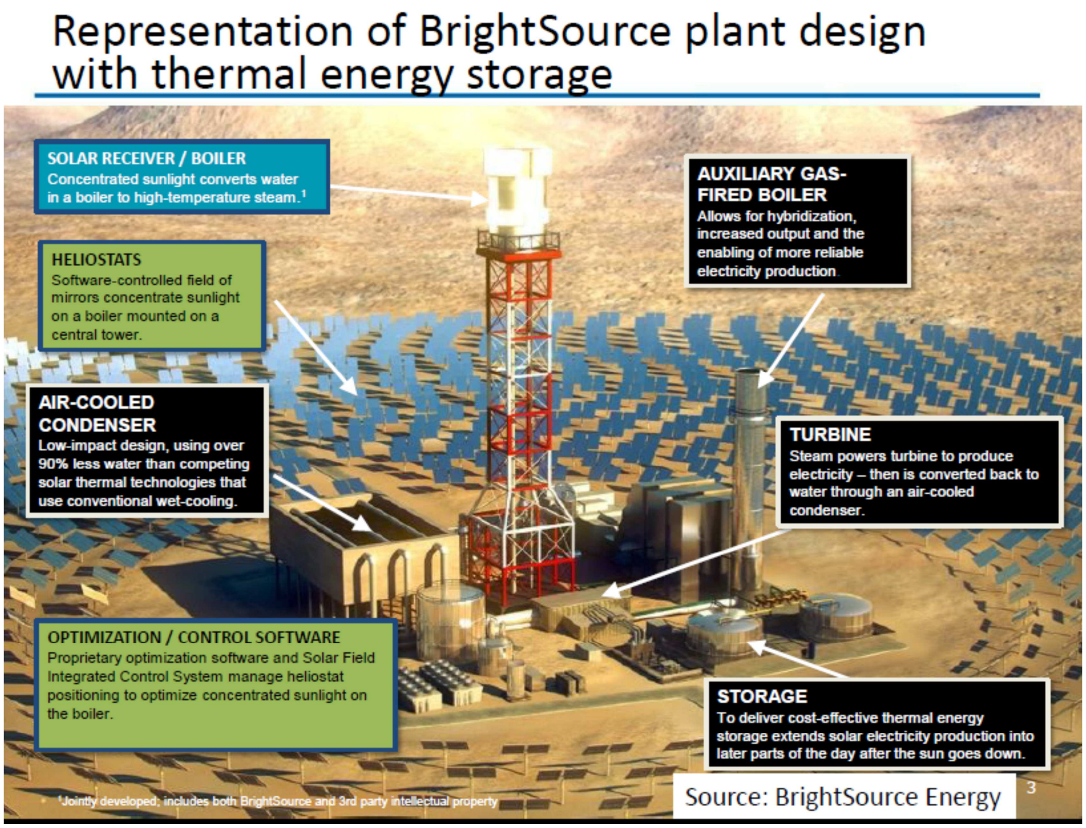
Project Description – Power Tower with Indirect Heating of Molten Salts

This section provides a brief description of a power tower with indirect heating of thermal energy storage utilizing molten salts. The design is based on a 200 MW BrightSource Energy project with 2 hours of thermal energy storage under contract to Southern California Edison. With this technology, a solar field consisting of thousands of flat mirrors on dual-axis tracking mounts are arranged around a tower, on which is mounted a solar receiver steam generator. The mirrors track the motion of the sun, reflecting sunlight onto the solar receiver. As in a traditional boiler, water is pumped through channels within the solar receiver, where it absorbs the heat of the reflected sunlight and becomes steam. Steam temperatures are typically in excess of 565℃.

During daylight, most steam produced in the tower is directed to a steam turbine, where it is converted into mechanical energy to turn a generator and thus make electric power. Simultaneously, the excess steam is used to heat the energy storage fluid, molten salt, by passing it through a heat exchanger. Hot steam and relatively cold molten salt enter the heat exchanger and cooler steam and hotter molten salt exit. The steam output from both the heat exchanger and the turbine, which has now given up most of its energy, is sent to an air-cooled condenser (ACC) where it is condensed back to water and ultimately pumped back up the tower to repeat the cycle. The hot molten salt exiting the heat exchanger is pumped into the hot molten salt storage tank and stored there for later use. The system is fully charged once all the salt has been pumped from the cold molten salt storage tank, heated in the heat exchanger, and pumped into the hot storage tank.

During night or other periods of no sun when electric output is desired, hot molten salt from the hot molten salt storage tank can be pumped through the same heat exchanger used for charging, but in the reverse direction. Water is similarly pumped through the heat exchanger in the reverse direction. In this process, the heat from the salt is transferred to the water, turning the water to steam and cooling the salt. The steam thus generated is sent to the turbine to generate electricity, and the cooled molten salt is sent to the cold molten salt storage tank. The storage system is depleted when all hot molten salt from the hot tank has been used to generate steam and pumped into the cold tank. The system is capable of operating at full capacity from a fully-charged thermal storage system for two hours. It can also be operated at lower capacities for longer periods of time, and can also operate in discharge mode in tandem with direct generation during periods of partially reduced sun in order to maintain full electric production.

Location	***Southern California***
Operational Status	In development
Ownership	TBD
Primary Benefit Streams	Energy, capacity, ancillary services
Secondary Benefits	Avoided integration costs, power quality
Available Cost Information	NA



Project Description – Power Tower with Direct Heating of Molten Salts

This section provides a brief description of a power tower with direct heating of thermal energy storage utilizing molten salts, based on SolarReserve's Crescent Dunes project. Crescent Dunes is currently under construction in Nevada and will be the largest molten salt power tower in the world when completed in 2013. Under its PPA with NV Energy, the project will deliver 500,000 MWh annually with a 110 MW steam turbine and 10 hours of molten salt storage, resulting in an annual capacity factor of 52%. Construction is well underway and plant commissioning will commence in early 2013. In California, SolarReserve is developing the Rice Solar Energy Project under a PPA with PG&E; with 150 MW, 8 hours of storage, and 500,000 MWh annually, it employs essentially the same technology as the Crescent Dunes project but with a more "peaking" configuration.

SolarReserve's technology uses an optimized circular field of mirrors which track throughout the day to focus sunlight on a central receiver atop a tall tower. Molten salt flows through the receiver and is heated directly by the sunlight. Hot salt is stored at over 560℃ and used to generate superheated steam o n demand at a consistent temperature and pressure. The steam powers a conventional steam turbine generator. Because the salt is both the receiver working fluid and the storage medium, this is commonly considered "integrated" molten salt storage.

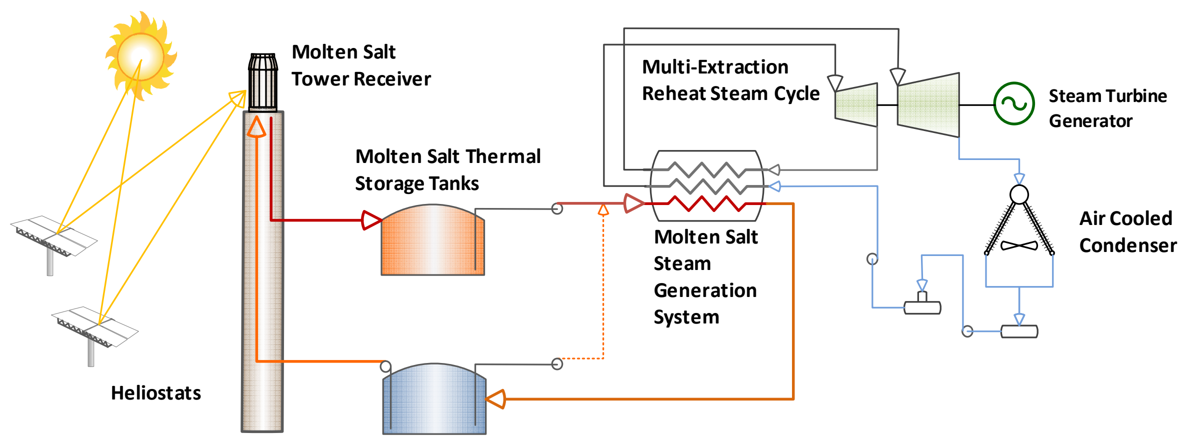


Figure 1 - Integrated Molten Salt Storage Process Flow Diagram

Direct heating of the molten salt, rather than heating salt with solar steam, allows energy to be stored and dispatched without multiple heat exchange steps. This integrated storage approach enables a project like Crescent Dunes to deploy a large amount of storage (e.g., 10 hours) efficiently and cost-effectively. Higher storage efficiency enables more flexible dispatch and multiple configuration options of the CSP plant (i.e., baseload or peaking). Integrated storage also allows the system to ride through intermittent cloud cover by simply slowing the flow of salt through the receiver, while direct steam systems may experience problems with steam condensing in the receiver during cloud cover. Riding through cloud cover and more efficient bulk storage were the primary motivations behind the DOE's advancement from direct steam tower at Solar 1 to an integrated molten salt receiver at Solar 2.

Figure 2 - Crescent Dunes project under construction near Tonopah, NV

Location	***Near Tonopah, Nevada***
Operational Status	Under construction, commercial operations in 2013
Ownership	SolarReserve, Banco Santander, and ACS Cobra
Primary Benefit Streams	
Secondary Benefits	
Available Cost Information	$135/MWh PPA price, $737M DOE loan guarantee, $260M equity investment.

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6.5 Zero-Emission Energy Storage and Rapid Response Peaking Plants

Clean Energy Systems, Inc. – Zero-Emission Energy Storage (ZEES) and Rapid Response Peaking Plants (RRPP) utilizing oxy-fuel technology

6.5.1 Description of Technology

CES has designed, manufactured, and is now marketing oxy-fuel combustion systems that will be the central component of new zero-emission power plants (ZEPP). CES developed its ZEPP technology largely as a result of PIER grants from the California Energy Commission (CEC). From these founding-grants, CES has emerged as the global leader in oxy-fuel power systems. Our partners include Siemens Oil & Gas, Maersk Oil, Paramount Resources and Southern California Gas Company. In cooperation with Siemens Power and the Department of Energy, CES is currently testing the world's first ZEPP system at its Kimberlina Power Plant in Bakersfield, CA.

The CES technology achieves zero emissions by combusting natural gas and/or renewable fuels in an oxygen environment. The resulting emissions are, effectively, 100% CO_2 that is compressed and permanently sequestered in enhanced oil recovery (EOR) operations. The zero-emission Tri-generation plants produce clean power, CO_2 for EOR, and potable water for commercial markets. See http://www.maerskoiltrigen.com/

The oxy-fuel process can provide significant energy storage (i.e. 100 MW/day) and return the power utilizing peaking turbines and mid to large size turbine generators as the power grid may require. Energy storage is achieved by utilizing surplus energy to produce liquid oxygen during off-peak hours and returning the energy as zero-emission power. The mid to large scale turbine generators (100-400MW) that would return the energy produce zero-emission power and be capable of providing zero-emission load balancing (ZELB) services to the grid. Utilizing the oxygen through rapid response peaking plants (RRPP at 20-50MW) would provide fast startup support services (1 minutes or less). The RRPP emissions would be emitted to the atmosphere but free of NOx and other pollutants.

6.5.2 End Uses

	End Use	**Large Scale Storage ZEPP/RRPP**	**Notes**
	Frequency Response	S/P	The ZEPP/ZEES facility has significant generation rotating mass that supports grid stability. In addition, the facility can add or off-load the energy storage load that will be approximately 100MW. The RRPP can be at full power in a minute to address numerous system issues.
ISO/ Market	Frequency regulation	S/P	The ZEPP/ZEES facility has significant generation rotating mass that supports grid stability. In addition, the facility can add or off-load the energy storage load that will be approximately 100MW. The RRPP can be at full power in a minute to address numerous system issues.
	Spin	P/P	The ZEPP/ZEES facility has significant generation rotating mass that supports grid stability. In addition, the facility can add or off-load the energy storage load that will be approximately 100MW. The RRPP can be at full power in a minute to address numerous system issues.
	Ramp	P/P	The ZEPP/ZEES facility can add or off-load the energy storage load that will be approximately 100MW.The facility is also capable of load following consistent with existing combined cycle technology. The RRPP can be at full power in a minute to address numerous system issues.
	Black start	S/P	The oxy-fuel ZEPP and RRPP facilities will be designed with black-start capability.
	Real-time energy balancing	P/P	The report "California's Energy Future – The View to 2050" identified the State's critical need for zero-emission load balancing (ZELB) power plants if it is to meet the existing GHG reduction targets. The ZEPP used to provide energy storage will provide energy balancing and load following services.
	Energy arbitrage	P/S	Utilizing a liquid oxygen design, a ZEPP would be able to provide 100 MWs of storage In the evening hours and return approximately 240MWs during the day or multiples thereof. Significant energy arbitrage could be realized.
	Resource Adequacy	P/P	It is expected that the ZEPP/ZEES and RRPP will meet RA requirements.
Generation	Intermittent resource integration: wind (ramp/voltage support)	S/P	The ZEPP/ZEES facility can add or off-load the energy storage load that will be approximately 100MW.The facility is also capable of load following consistent with existing combined cycle technology. The RRPP can be at full power in a minute to address numerous system issues.
	VER/ PV shifting, Voltage	S/P	The ZEPP/ZEES facility can add or off-load the energy

	sag, rapid demand support		storage load that will be approximately 100MW.The facility is also capable of load following consistent with existing combined cycle technology. The RRPP can be at full power in a minute to address numerous system issues.
	Supply firming	P/P	The ZEPP/ZEES facility can add or off-load the energy storage load that will be approximately 100MW.The facility is also capable of load following consistent with existing combined cycle technology. The RRPP can be at full power in a minute to address numerous system issues.
Transmission / Distribution	Peak shaving: load shift	S/P	See Energy Arbitrage and Real-Time Energy balancing.
	Transmission peak capacity support (deferral)	S/P	The RRPP has a small footprint and can be located throughout a service territory. ZEPP facilities need access to EOR operations via a CO2 pipeline.
	Transmission operation (short duration performance, inertia, system reliability)	S/P	The RRPP has a small footprint and can be located throughout a service territory. ZEPP facilities need access to EOR operations via a CO2 pipeline.
	Transmission congestion relief	S/P	The RRPP has a small footprint and can be located throughout a service territory. ZEPP facilities need access to EOR operations via a CO2 pipeline.
	Distribution peak capacity support (deferral)	S/P	The RRPP has a small footprint and can be located throughout a service territory. ZEPP facilities need access to EOR operations via a CO2 pipeline.
	Distribution operation (volt/VAR support)	S/P	The RRPP has a small footprint and can be located throughout a service territory. ZEPP facilities need access to EOR operations via a CO2 pipeline.

6.5.3 Costs & Other Variables

ZEPP can produce power that is competitive with today's alternatives. The incremental capital that is necessary for the required oxygen supply and CO_2 systems is largely offset with the higher turbine efficiencies, CO_2 and potable water revenue streams. These plants can also provide a number of output products to the grid including:

1. Zero-Emission Power Production (ZEPP)
2. Zero-Emission Energy Storage (ZEES)
3. Zero-Emission Load Balancing (ZELB)
4. Rapid Response Peaking Power (RRPP)

The above services will be provided based on market conditions and the presence of acceptable tariff schedules that make such services financially feasible. It is expected that the tariff conditions will provide negotiating flexibility when the provided services are integrated and operationally dependent with each other.

6.5.4 Example Projects

CES has developed the world's most advanced oxy-fuel test facility at its Kimberlina Power Plant in Bakersfield, CA. The facility is utilized to develop and test oxy-fuel power systems. The facility has hosted numerous visitors from governments, research institutions, the power industry and energy developers.

Today, the facility has a number of operating systems. These include:

1. A 20 MWt power system that drives a 6 MWe steam turbine. With the initial startup of this unit, it became the world's first oxy-fuel power plant; producing power and EOR ready CO2 emissions.
2. A 179 MWt oxy-fuel combustion system that drives a J-79 gas turbine, known as the LM1500. The system was commissioned in 2009 and is, effectively, the RRPP referenced above.
3. As a result of a $40 million grant from the Department of Energy, in 2011/12 CES developed a 2nd generation oxy-fuel turbine (OFT-900) that is now being made operational. This is the world's first oxy-fuel turbine and is a joint development effort between Siemens Power and CES. After testing during the first half of 2013, the power system will be placed into commercial operations, producing zero-emissions power, potable water and CO2 for EOR. With the addition of an air separation unit (ASU), this unit could provide the energy storage discussed above. It is expected that Siemens will place this unit into commercial production in the near future.

CES and its partners have determined that the oxy-fuel, zero emission power system is now ready for commercial operations. The company is developing a number of projects including:

1. A 200MWe oxy-fuel power generation system that will produce 2,000 TPD of CO2. In this project, the CO2 that would have typically been vented into the atmosphere will be used for enhanced oil recovery and sequestered. This U.S. project will utilize the OFT-900 turbine design and be capable of load following and providing off-peak energy storage services if market conditions justify..
2. A series of plants, strategically located to provide zero emission power, CO2 for EOR operations and potable water to the local communities. These installations will also be capable of providing energy storage and ZELB service if warranted by regional conditions.

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7. Concluding Questions

What are the considerations for cost-effectiveness?
Cost-effectiveness should compare the net value of projects, that is the difference between revenues that can be realized and the fixed and variable costs of the project. The considerations of net value are listed in section 3.1 and additional considerations for costs in section 3.4.

Is ES cost-effective for this use?
It is too premature to answer this question at this time. The Phase 2 of the Energy Storage OIR is defining and applying cost-effectiveness methodologies to make a comparison across technologies.

What are the most important barriers, where resolution will make a large and immediate impact? Which of these are unique to energy storage vs all resources?
This is an issue where there was significant disagreement among stakeholders. The most significant impediments that are unique to energy storage are lack of clarity around resource adequacy value and lack of commercial operating experience. Many of other impediments in section 4 apply to all resources.

What are the most important barriers preventing or slowing deployment of ES in this use?
The capital intensive nature and relatively long development cycle require both long term procurement plans that can value the benefits of pumped storage as well as multi-year procurement processes and or long-term contracts.

What policy options should be pursued to address the identified barriers?
As discussed above, the most important policy options for California regulators include: 1) the addition of a flexible capacity requirement into the RA program, 2) multi-year procurement and/or long term contracts for resource adequacy and other capacity-related ancillary services 3) further development of spot market products to procure flexible ramping and load following to complement the requirements added to the resource adequacy program 4) improved tools and methodology for cost-effectiveness evaluation.

Should procurement target or other policies to encourage ES deployment be considered for this use?
There was significant disagreement between the stakeholders the issue of procurement targets. LSEs, who would have storage targets imposed onto them, and several technology providers were opposed to procurement targets. Many of the storage technology providers supported having procurement targets.

However, as explained above, policy changes and enhancement to existing energy market rules are necessary to encourage cost effective deployment of energy storage. Primarily, the State needs to recognize the operational uses where energy storage technologies are cost effective and provide benefits to ratepayers.

8. Appendix

Draft – (This section is still under development)

Optionality Value in a nutshell

Optionality Value (listed in Section 3.3 Other Beneficial Attributes) refers to the value created by the ability to *delay procurement commitments until a future date when there is reduced uncertainty regarding: (1) need, (2) future procurement choices, or (3) future resource costs.*[6] By delaying a commitment, IOUs may avoid procurement of resources that do not match grid needs, and may lower their overall expected costs.

Typically in California, the CPUC orders IOUs to procure the FULL quantity (MW) of generation necessary to meet an expected need. However, future needs are uncertain. The actual need may be less than the expected need, or be a need of different attributes. Thus, procuring the FULL quantity may result in over-procurement, or procurement that does not optimally fit the grid needs.

The availability of short lead time resources enables an alternative approach, in which the CPUC directs IOUs to procure a quantity LESS than the full quantity (MW) of the expected need. At later date, if the full need develops, the IOUs will procure additional resources, which will at that point need to be short lead time resources. If the need does not develop, no additional generation need be procured. The ability to delay procurement commitments may result in a lower expected cost. This is the source of Optionality Value.

Different types of short lead time resources

Short lead time resources include many storage resources (most storage resources excluding pumped hydro and geological compressed air storage) as well as certain fossil resources (some gas turbines).

How developers of short lead time resources might capture some of the optionality value

Optionality Value does not make short lead time resources become "worth more." Rather, optionality creates opportunities for short lead time resources that are not available to long-lead time resources. These opportunities are created when IOUs do not procure the FULL quantity of expected need. The opportunities for short lead time resources include the following:

1. An IOU might choose to procure an Option (a contract giving the IOU the right to procure generation in the future at a specific price) from a developer of a short lead time resource
2. The IOU might defer procurement of a certain amount of capacity. Should need develop in the future, an IOU would then have an RFO in which only short lead time resources would be eligible.

[6] Storage has various "planning factors" that may be of value that are *not* included in Optionality. See discussion at the very end.

Note that in neither case does the IOU commit to building the short lead time resource up front. In (1), the IOU does provide an immediate payment to the developer to purchase the Option. However, as part of the Option contract, the IOU will require *significant* collateral. This collateral is required to ensure that the IOU will be made whole if the developer does not deliver on the new generation, should the IOUs execute the option. (IOUs are unlikely to accept exposure related to the risk that the developer cannot deliver according the option contract.)

Different sources of uncertainty may lead to multiple sources of optionality

Stakeholders have identified several sources of uncertainty regarding future grid needs and procurement choices.[7] Delaying procurement commitments may allow better certainty on the following variables, which could result in a better procurement choice.

- Grid needs – quantity (MW): uncertainty over grid needs; delaying a commitment may avoid over-procurement of generation resources
- Grid needs – location: uncertainty over optimal location for new generation; delaying a commitment may result in better located resources
- Grid needs – function: uncertainty over the purpose/function required by future resources; delaying a commitment could result in procuring resources that better meet future grid needs.
- Technology options: uncertainty over future commercially viable technology; delaying a commitment may allow selection of a new technology that is the better least-cost/best-fit solution
- Cost: uncertainty over the future costs of various resources; delaying a commitment may allow to select a resource that has recently become the least cost resource.

The risks of delaying—or not delaying—procurement commitments

Delaying a procurement commitment eliminates certain procurement options, namely any resource that requires a longer lead time. (For the purpose of the analysis, "time 0" should be determined to be the last point in time in which a long lead time resource could be procured to meet an expected need. Thus, by definition, delaying a procurement commitment eliminates the choice to procure certain long lead-time resources to meet the identified need.) If the short lead time resource is more costly than the long lead time resource, parties must be willing to accept the fact that a higher cost resource may need to be procured in the future. However, parties ought to be willing to accept this risk in exchange for a lowered expected cost.

At the same time, procuring the FULL quantity of resources is also not without risk: Full procurement at time 0 eliminates the options to procure other resources in the future, resources that could potentially be cheaper or better fit the future needs of the grid. Additionally, if IOUs are to procure the FULL quantity of resources, parties must be willing to accept the fact that over-procurement may occur, and

[7] Not all stakeholders agree that all of these variables would meaningful/practical/effective/worthwhile to incorporate into an analysis of optionality.

that this procurement decision may result in a higher expected cost. The fact that this is the status quo should not be taken to indicate parties “accept” this situation.

Optionality value must be calculated in the context of a procurement planning process

Critically, analyzing and capturing Optionality Value requires a risk-based, probability analysis of procurement options *including a range of potential values for uncertain variables with associated probabilities for those values.* Optionality value can only be analyzed if these probabilities are stated, using a decision tree expected value framework, or a monte-carlo simulation.

The optionality value is highly dependent upon these probabilities. For example, if we assume a 90% chance of needing 1000MW and 10% chance of needing only 900MW, the optionality value will be relatively small. If we assume a 50% chance of needing 1000MW and a 50% of needing 500MW, the optionality value will be much greater.

A decision tree or monte-carlo similar provides expected costs for different decisions made both at Time 0 and in the future. These costs may be used to identify the optimal decision today, as well as the optimal decisions made in the future, based on future conditions.

Optionality Value may or may not be greater than zero

A hypothetical procurement planning process that does *not* allow delayed commitment (i.e., must procure resources today to meet 100% of expected need, however that need is calculated) will result in some expected cost. *Expanding* the decision tree analysis to allow delayed procurement will result in more choices, each with their expected costs. One of these new options involving a delayed procurement commitment *may* result in lower overall expected cost. However, it is also possible that the original procurement decision remains the optimal (least expected cost) option. In other words, adding the option of delayed procurement may or may not reduce the overall expected cost. Thus, the optimal solution may or may not change when delayed procurement is allowed. *In other words, the consideration of optionality value is <u>not</u> guaranteed to change the ultimate procurement decision or expected cost.* <u>See the attached decision tree examples for where optionality value is and is not relevant.</u>

Sometimes the short lead time resources may not receive any tangible benefit, even if delayed procurement is allowed. Here are two examples:

a) The decision tree analysis shows that the optimal solution is to procure the full (highest expected need) using long lead time resources. The availability of short term resources does not lower expected costs. In this case, there is no optionality value. This is shown in the “Case 2” decision tree, attached.
b) A certain quantity of procurement is delayed, but then the uncertainty is resolved such that there is <u>no additional need</u>. In this case, no additional short lead time resources are procured. This outcome is shown in the bottommost branches of the “Case 1a” and “Case 1b” decision tree. In this case, the existence of short lead time resources and the availability of delayed procurement avoided

over-procurement and saved ratepayers money. However, the only way the short lead time resource developer could benefit is if the IOU procured an option. The developer would receive payment for the option, though the developer does not build generation.

Optionality Value does not make a given resource “worth more”

Because the optionality value is integral to a given analysis of procurement options and potential needs, one cannot assign an “optionality premium” to a resource. Instead, one can calculate the potential for reduction in expected total costs by allowing the IOU to delay a procurement commitment. This savings represents the upper limit an IOU would be willing to pay for an option to procure the resource at a later date. But this value is separate and distinct from the actual NPV of the resource.

Finally, this is a conceptual discussion. If, when, and how this should be implemented in LTPP is a whole other conversation.

<u>**Conclusions**</u>

- Optionality value is created by the ability to delay procurement commitments and reduce uncertainty
- Optionality can only be determined in the context of a procurement planning process in which probabilities are established for uncertain variables.
- Consideration of optionality may or may not change the total expected cost of procurement
- **Optionality value does not have meaning outside of the context of a procurement planning process. A positive dollar value for “optionality premium” should never be assigned to any given resource**

* * *

“Planning Factors” that may have value that are distinct from Optionality

Storage resources have many favorable attributes or “planning factors” that are *distinct from optionality value.* These attributes are components of a competitive solicitation process seeking to meet a defined need; they are independent from a discussion of the potential value of delayed procurement commitments. Planning Factor (1) below should be incorporated in a developer’s offer price. Where grid needs indicate Factors (2), (3), and (4) will provide value, the solicitation guidelines should specify the desired attributes that IOUs will be valuing. (IOUs generally do not release details on their valuation models. IOUs are required to fairly and accurately evaluate offers, and an Independent Evaluator reviews procurement decisions. To the extent that some attributes mentioned below have not previously been the focus of procurement processes, the Storage OIR could represent a forum for exploring how these attributes can be valued.)

1. <u>Fast build time / less capital deployed</u> far in advance of operation. This time value of money savings reduces financing costs, and should result in a lower offer price

2. Modularity: where an assessment of grid needs determines that many smaller resources offer greater value than fewer larger resources, the modularity of storage will allow an offer to be proposed that better matches grid needs, and will be ranked higher in quantitative value or qualitative best-fit calculation
3. Mobility: where an assessment of grid needs determines that there are a series of sequential, sort term needs, the cost of a single, mobile resource may be cheaper than multiple permanent installations. Such a mobile resource would be ranked higher due to its lower cost, all else being equal
4. Multiple purposes: A single resource that can satisfy multiple identified grid needs may be cheaper than alternative resources than can satisfy only a single need. Such a multi-purpose resource would be ranked higher due to its lower cost, all else being equal. The fact that a multi-use resource can be repurposed at a future date for different needs may allow it to provide different benefits from those originally intended. This repurposing capacity may reduce the risk associated with its ability to access future benefit streams. The actual repurposing value of an asset is highly dependent upon its technical capabilities, the specific circumstances of its original deployment, and the ability to provide any alternative benefits in the future.

CASE 1a: In this case, the Short Lead Time resource is assumed to cost 20% more than the long lead-time resource. However, the probability of low need means that delaying procurement of some MW results in overall lower expected cost. This is true even though, should the high need develop, the cost of the short lead time resources would be higher than the cost of long lead time resources.

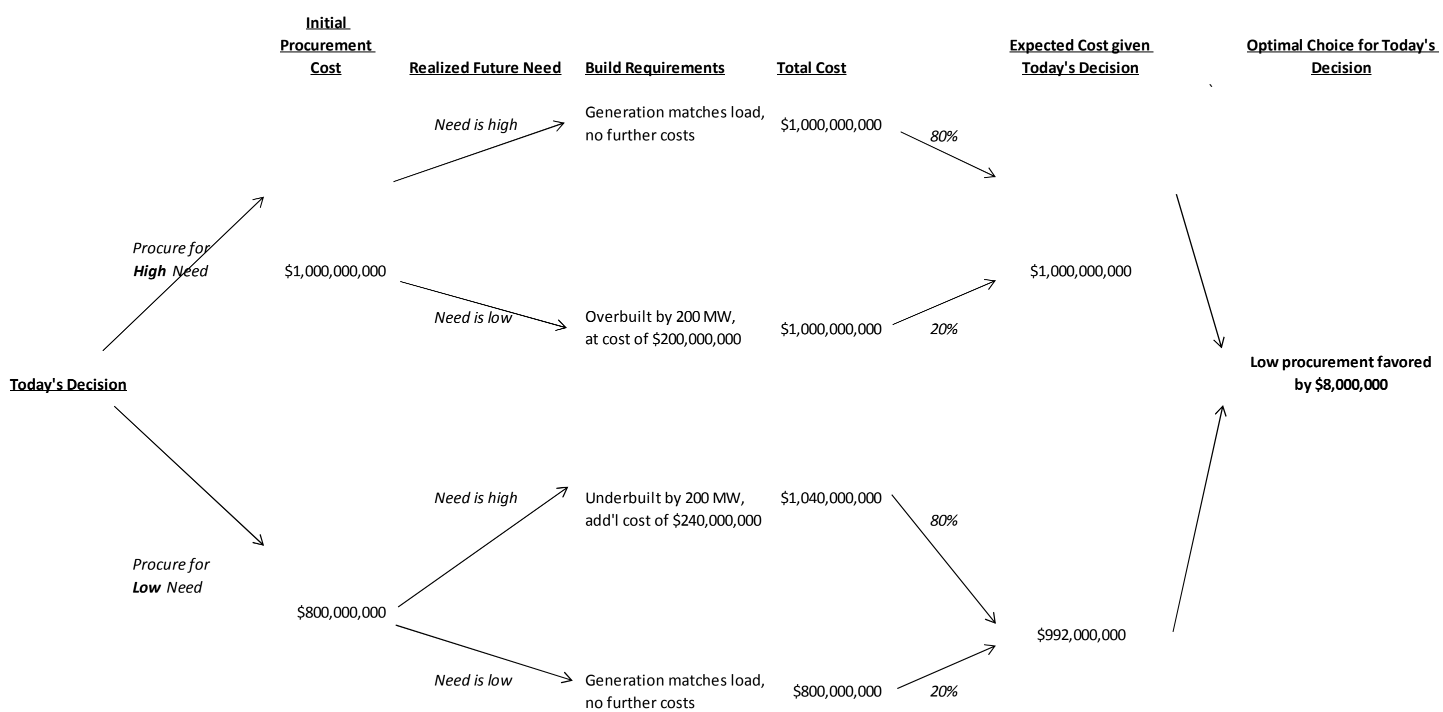
Optimal action today: Procure only 800MW. If necessary at a later point in time, procure an additional 200MW (short lead time resources). In this case, the IOU may want to procure an option for future construction of 200MW. Assuming the strike price of the option is still 1,200,000/MW, the IOU would be willing to pay anywhere from zero to $8,000,000 for the option to build 200MW. Actual willingness to pay would depend on the IOUs expectation of future prices, and tolerance to the risk of future prices going up.

Control Panel

Case	Probability	Need (MW)
High Need	80%	1000
Low Need	20%	800

Technology	Cost (Today's $ / MW)	Potential Quantity (MW)
Short Lead Time Resource	$1,200,000	200
Long Lead Time Resource	$1,000,000	800
Long Lead Time Resource	$1,000,000	1000

Results



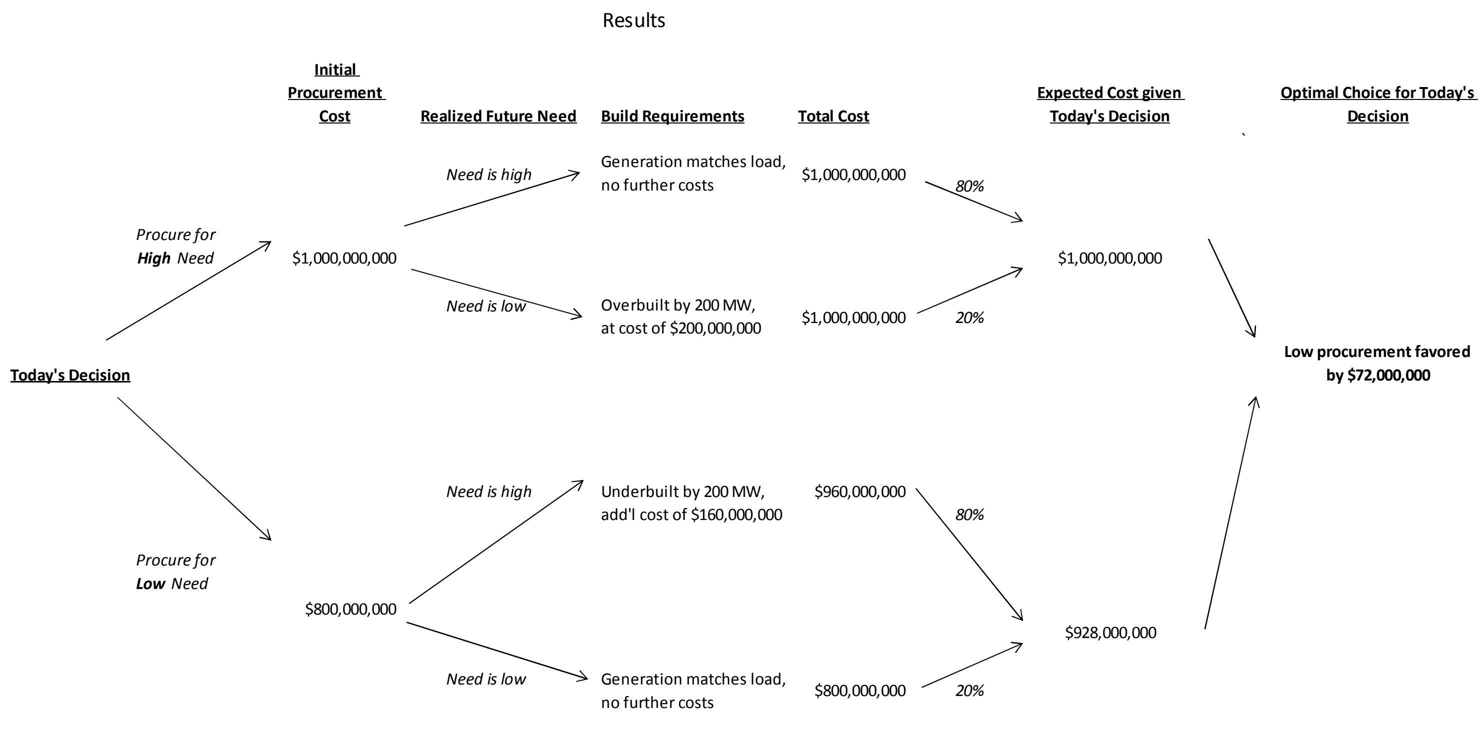
Case 1b: The expectations of need are the same as above, but in this case, the short lead time resource developer is projecting a future cost of only $800,000/MW, and is willing to create an Option at that strike price. Assuming the *current* price of short lead time resources is greater than 1,000,000/MW, the IOU will build 800MW of long lead time resources, and the IOU would now be willing to pay anywhere from zero to $72,000,000 for the option to procure 200MW at $800,000/MW price, depending on future expectations.

If the IOU believes the future market price of short lead time resources to be greater than $800,000, they are more likely to be willing to pay a higher price for the option. However, if the expected future market price of short lead time resources is far above the strike price, the IOU will demand much more collateral as part of the Option contract.

Control Panel

Case	Probability	Need (MW)
High Need	80%	1000
Low Need	20%	800

Technology	Cost ($ / MW)	Potential Quantity (MW)
Short Lead Time Resource	$800,000	200
Long Lead Time Resource	$1,000,000	800
Long Lead Time Resource	$1,000,000	1000



CASE 2: In this case, the short lead time resource is assumed to cost 15% more than the long lead time resource, more favorable than Case 1a. However, unlike the previous cases, the high need case is now expected with 90% probability. Despite availability of short-term resource, high probability of “high need” results in optimal decision of procuring FULL quantity today. There is no consideration of procuring an option, as no short lead time resources will be procured.

Control Panel

Case	Probability	Need (MW)
High Need	90%	1000
Low Need	10%	800

Technology	Cost ($ / MW)	Potential Quantity (MW)
Short Lead Time Resource	$1,150,000	200
Long Lead Time Resource	$1,000,000	800
Long Lead Time Resource	$1,000,000	1000

Results